LEEDS PHILOSOPHICAL AND LITERARY SOCIETY.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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A. A. COMMON, LL.D., F.R.S., President, in the Chair.

William Banks, 30 Corporation Street, Bolton, Lancashire ; and

Alfred Ernest Young, Assoc. M. Inst. C.E., Trigonometrical Survey of Perak, Taiping, Perak, Straits Settlements,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Lewis Evans, J.P., F.S.A., Barnes Lodge, King's Langley, Herts (proposed by Sidney Waters) ;

John Anderton Greenwood, Solicitor, LL.M., B.A., Brooklyn, Earl's Court Square, S.W. (proposed by Capt. D. Forbes).

Seventy-six presents were announced as having been received since the last meeting, including, amongst others :—

W. T. Lynn, Remarkable Eclipses ; T. K. Mellor, A Handy Map of the Moon ; F. Tisserand, Traité de Mécanique céleste, tome iv., presented by the authors ; three photographs of Comet Rordame-Quénisset, presented by the Lick Observatory.

Some Notes on the Use and Adjustment of the Cœlostat. By H. H. Turner, M.A., B.Sc., Savilian Professor.

The name "cœlostat" was suggested by Mons. G. Lippmann (*C.R.* cxx. No. 19) for that form of heliostat in which the mirror rotates round an axis in its plane, and parallel to the Earth's axis, once in two days. A telescope fixed to the Earth and pointed to such a mirror will always see the same stars, as though they were attached rigidly to the Earth. The instrument seems specially suitable for eclipse work, and three such will be sent out in the forthcoming eclipse expeditions to Japan and Norway, organised by the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies. One of these has been tried at Oxford during the last few months, and the following notes on its adjustments &c. may be found useful by others working with the instrument.

Support for Cœlostat.

This should be as firm as possible—stone or brick, with concrete foundation, if there is time and opportunity. No precautions to ensure steadiness are to be looked upon as unnecessary. It is a great comfort to feel that the adjustments, once made, are permanent. But, in case nothing better is available, a very good support can be made of the wooden box for the instrument, (especially if it be filled with sand, or sand and stones), placed on the soil. A cœlostat was mounted on its box, without any filling of sand, at Oxford; the box resting on two planks scraped into the ground and levelled. The adjustments had only altered by a few minutes of arc in a fortnight, probably through the yielding of the wood at the points of greatest pressure from the weight of the instrument.

When placed on the box, the height of the centre of the mirror is 3 feet 6 inches, and the instrument is suited for work with a horizontal telescope. But if the telescope is to point downwards, as will probably be found most convenient in general (see below "*Position of Telescope*"), the box will be unnecessary, and a flat stone or a flat board will be all that is required. Perhaps the iron base might rest on the bare earth if sufficiently firm.

Support for Telescope.

No means of securing steadiness are thrown away, but even rougher methods may do here. No permanence of adjustment is required—just the contrary, for the telescope must be shifted to follow the Sun in declination. But when once pointed on the Sun, there should be some method of clamping it tightly, so that the putting in and out of the plate and the opening of the exposing shutter, &c., may not shake it. But it will readily be seen that even the flimsiest method of holding the telescope in this way is superior to that of the ordinary equatorial.

For the telescope in the horizontal position, the following method was adopted at Oxford with good results. Two parallel horizontal bars were screwed to posts driven into the ground, forming virtually a horizontal table. The telescope (a wooden tube of rectangular section) could be shifted about on these bars at will, and when properly pointed two or three spare clock weights placed on the top of it, and one or two very thin wooden wedges pushed under the tube with the fingers made a very steady mounting.

If the telescope is not to be horizontal, one bar must be higher than the other, and the slipping of the tube lengthways may be prevented by wooden fillets on the tube, which should come against the bars. Instead of the weights, which might slip down the tube unless similarly held by fillets, a rope might be bound once or twice round the tube and firmly attached to the bars.

Huts and Coverings.

In the early experiments at Oxford I started with the idea of keeping the telescope in the hut and putting the cœlostat outside. I think this is wrong. The cœlostat ought to be indoors and the telescope outside, for several reasons.

(*a*) If a hut is built over the telescope it is very difficult to avoid cutting off some of the sky, especially if any attempt is made to cover the cœlostat also. I need not here reproduce the details of suggested plans, of which several were considered. Those who come to work with the instrument will quickly realise the difficulties.

(*b*) The telescope can easily be lifted indoors. No permanent adjustment is required, as above remarked, and the supports can be left outside in the weather.

(*c*) It is, of course, more comfortable for the observer to be indoors if possible, especially at night in cold weather. But on the occasion of an eclipse considerations of this kind are not much to the fore ; and there are other reasons why he would prefer to be in the open.

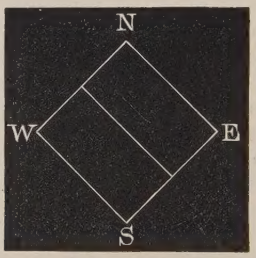
(*d*) On the other hand, the cœlostat ought to be indoors. The metal work is liable to rust with exposure to weather—even under a tarpaulin, say—and the mirror will dew if it is not warmer than the outside air. By placing cœlostat and clock in a hut, where, if necessary, an oil stove can be lighted to warm the place, the dangers of rust and dew are greatly diminished. It ought to be made *quite certain* that the mirror is warmer than the outer air before opening the hut to observe the eclipse : for, if the mirror dews over, there may not be time to get the surface clear again before totality commences.

(*e*) If the cœlostat is indoors it can be cleaned or adjusted in various ways, clock rated, &c., during inclement weather, when it could not otherwise be uncovered.

For these and other reasons I propose to put the cœlostat in the hut, which the observer will in any case require for storing boxes, books, and instruments, and which may be used also as a dark room, and even as a sleeping apartment. The cœlostat should be at the south side or corner of the hut, so that when a southern window or door is opened a good view of the zodiac is obtained.

As regards the particular form of the hut much may be left to be settled for the particular place, occasion, or observer ; but as there are many advantages in uniformity, it may not be amiss to suggest a simple plan as a "working hypothesis," for subsequent modification.

If the hut is to be made on the spot one great desideratum is simplicity. Let us start with the simplest form of hut, viz. the five faces of a cube, the ground forming the sixth. The side of the cube may be taken as 10 feet. The roof, however, should be pent-house, not flat ; and we may perhaps reduce the height from 10 feet to 8 feet at the cross-bar, and 6 at the sides. There should be at least one door and one window ; and we may make use of these to admit light to the cœlostat. Place the hut with its *corners* N., E., S., W., and the cœlostat at the S. corner. Then a door in the S.E. face, extend-



ing from the S. corner to the middle of the face, would admit the Sun in the morning, and a door in the S.W. face would similarly admit it in the afternoon. The doors would be rather wide (5 feet), but this would not matter. They should be hinged on posts in the middle of the faces (one of which would be necessary to support the cross-bar of the roof), and they would then close against the post at the S. corner. This post would be practically the only obstacle to a clear view for the cœlostat ; for the roof would only cut off the sky near the zenith, which is not wanted for eclipse work.

Windows may be added according to taste and fancy, or may be dispensed with altogether in favour of an open door, for it would be rather cruel weather if one of the two doors could not be opened without admitting the rain. Half of the hut may be partitioned off as a dark room, if thought desirable, by a partition

along the roof cross-bar, and the part of the hut north of the cross-bar may be extended at pleasure to give sleeping room &c.

It will be noticed that there is a post on the meridian of the cœlostat, and this might be thought a disadvantage. It might obscure the view of the adjusting theodolite just on the meridian, and if we were taking transits this would be a drawback ; but as for adjusting an equatorial we only want a view *near* the meridian no harm is done, and if we use the image of the Sun in the telescope itself, by reflection from the mirror (see below) to adjust by, even the meridian need not be cut off seriously. If the actual meridian view is important the cœlostat may be placed slightly to one side of the post, or finally, it is not difficult to dispense with this post altogether.

Position of the Telescope.

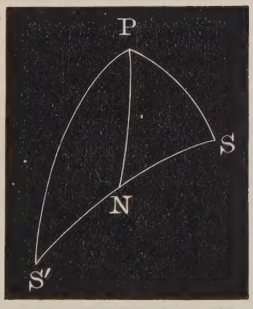
This may be considered from two points of view :—

(1) *Generally* without reference to the latitude of the place or time of day.

(2) *Locally, i.e.* with reference to the altitude and azimuth.

Let us first take the general considerations, viz. *inclination* of telescope to mirror, and *distance* from mirror.

The *inclination* of direct or reflected ray to mirror is a minimum when the star or sun is in the same hour circle as the telescope. This hour circle is of some importance and is frequently to be referred to, and it will be convenient to have a short designation for it. I cannot think of any which quite satisfies me, but perhaps the letters T.H.C. (telescope-hour-circle) would do. They will be used in this paper to denote the great



circle through the poles and the telescope. Thus if P be the Pole, S the star, N the normal to the mirror, and S′ the image of the star, PS′ is the T.H.C., and we have the relations

$$PN = 90^\circ$$

$$NS = NS' = i$$

$$\angle NPS = \angle NPS' = \tfrac{1}{2}h$$

$$PS = 180^\circ - PS' = p = 90^\circ - \delta.$$

where p is the N.P.D., or δ the declination, of the star, h its hour angle *reckoned from the* T.H.C., and i the inclination of either direct or reflected ray to the mirror-normal.

Further

$$\cos i = \sin p \cos \tfrac{1}{2}h = \cos \delta \cos \tfrac{1}{2}h.$$

The following small table shows the way in which i changes with h for different declinations in and near the zodiac.

Star's Hour angle from T.H.C.

Decl.	h 0·0	h 0·5	h 1·0	h 1·5	h 2·0	h 3·0	h 4·0	h 5·0
°	°	°	°	°	°	°	°	°
0	0·0	3·8	7·5	11·3	15·0	22·5	30·0	37·5
10	10·0	10·6	12·4	15·0	18·0	24·5	31·5	38·6
20	20·0	20·3	21·3	22·8	24·8	29·7	35·5	41·8
30	30·0	30·2	30·8	31·9	33·2	36·9	41·6	46·6

The inclination of incident to reflected ray will be double this in all cases, but this double angle does not much concern us.

Owing to this inclination of the rays, the circular mirror will yield an available cylinder of rays *elliptic* in section. The major axis of the ellipse is always equal in length to d, the diameter of the mirror; but its direction depends on h, the hour-angle from T.H.C. The minor axis is of length $d \cos i$. We can generally keep i less than 24° for eclipse work; and thus the minor axis for a 16-inch mirror is not less than $14\frac{1}{2}$ inches. But it may be important to take account even of this small diminution. When $h=0$ the major axis of the ellipse is perpendicular to the polar axis for objects of all declinations, but it rotates as h changes. If the telescope is not circular in section (*e.g.* if it is a combination of two telescopes) it may be advisable to arrange that the long axis of the telescope section corresponds in direction to the major axis of the ellipse, which is always perpendicular to NS′. The angle NS′P represents the amount of rotation of the major axis from its position when the star is on the T.H.C. If we put α for this angle we have

$$\tan \alpha = \tan \tfrac{1}{2}h \sec p.$$

Thus α can be readily calculated. For declination 16°, as in the eclipse of 1896 August 9, we have the following values for α at different hour angles from T.H.C. :—

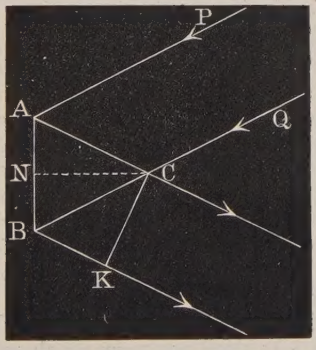
h	α	h	α
h	°	h	°
0·0	0	1·5	36
0·5	13	2·0	45
1·0	25	2·5	51

On the occasion of an eclipse it will generally be possible to arrange that the Sun should not be far from the T.H.C. (unless the Sun be very near the equator), and then the major axis of the ellipse is nearly perpendicular to the polar axis of the Earth or cœlostat. If, however, the Sun is on the equator, we cannot observe it in the T.H.C., for the telescope will get in the way; and then the major axis will be more nearly *parallel* to the polar axis.

As regards the *distance* of the object glass or glasses from the mirror: this must not be too great since the field of view is of finite angular dimensions; nor again too small, or the telescope will be in the way of the incident light.

The former limit depends on the diameter of the field to be photographed. For the Abney lenses, in general use for recent eclipses, a plate 6 inches square is used at the focal length of $5\frac{1}{4}$ feet. The angular distance of a side from the centre is thus nearly 3°, and of a corner more than 4°. Thus the cylindrical projection of the object glass must have a margin of 3° or 4°. For the other lens mounted alongside in the double tube the angular radius of the field is not so great, owing to the enlargement of the image; but we want a radius of 2° if possible. [It may be here remarked that although detail of the corona is not visible to the eye near the edges of the plates, the density of deposit has been measured on these plates right up to the edge, and found to have by no means reached uniformity, and for some reasons even larger plates would be better.] Hence we want an outside margin of 5° or 6° on the mirror to be safe. At a distance of the object glasses from mirror of 3 feet this would mean $3\frac{1}{2}$ inches to be added to the distance between the outside edges of the lenses, which is 10 inches. Hence we should not go much further away than 3 feet to be safe.

As regards the inferior limit of distance, if A B be the mirror, P A, Q C the incident, and A C, B K the reflected rays,



it is clear that the front of the telescope should not come nearer than the position C K (for parallel rays and a tube filling the

whole section C K). The distance C N is $\frac{1}{2}$ AB cotan. inclination or for a 16-inch mirror, C N is as follows for different inclinations :—

i	CN	i	CN
5°	91 inches	25°	17 inches
10	46 „	30	14 „
15	30 „	35	11 „
20	22 „	40	10 „

Since the tube is smaller than the mirror the above limits are tolerably safe ones ; but the angular radius of the field should be added to the inclination for the central ray in taking C N from this table. For the present eclipse, where $i = 16° +$ field $= 20°$ say, the distance 3 feet seems quite safe even when the Sun is on the T.H.C.

Local considerations.—The azimuth of the telescope will not much matter, only its inclination to the horizon.

(*a*) There are some conveniences in having the telescope horizontal, and then it must be placed in either the rising or setting points of the Sun's image in the mirror. The inclination of the rays to the mirror may, however, be too large for convenience in this position. This inclination can be seen at a glance from the table on p. 412, entering the table with the Sun's declination on the left, and at the top the difference between the time of totality and the time of rising (or setting) of the Sun's image. Thus for Vadso the *Sun's image* (*i.e.* body of equal and opposite declination to Sun) rises at $20^h{\cdot}5$, and the time of totality is 18^h, the difference being $2^h{\cdot}5$: and the Sun's declination is 16°. Hence the inclination i is about 24° if the telescope be horizontal. For Kushiro the time of totality is $3^h{\cdot}3$, and the Sun's image sets at $5^h{\cdot}0$, the difference being $1^h{\cdot}7$. Hence $i = 19°$ for the horizontal position.

(*b*) The meridian may often be a good place for the telescope. A side shift then does not affect the position of the image in declination, and this may be a convenient arrangement. The orientation of the image is also conveniently disposed.

(*c*) But unless the Sun's declination is very small it may be best to arrange so that the Sun at totality is in the T.H.C. It will be inclined to the horizon, but this is a positive convenience when the inclination is not too great. The plate-holders remain in position by gravity alone, without spring supports. The cœlostat can be on the ground and yet the observer work at a convenient height.

(*d*) Intermediate positions may be selected to combine any of these advantages. It does not very much matter indeed where the telescope is so long as totality does not occur too far from the T.H.C.

Adjustments.

Adjustment of rate of clock.—This is put first because it should be independent of the place, and should be settled before starting on the expedition. The number of revolutions which the governor (or of some part of the clock of which the revolutions can be counted) should make in a minute can be determined, either by counting the number of teeth in the driving sector and different wheels of the train, or by direct observation of Sun or stars; and thus the clock can be regulated with a good watch indoors on a wet day if necessary. If possible, the driving-clock should be arranged to strike every minute, which would save tedious counting.

Adjustment of altitude and azimuth.—A declination theodolite is provided which can be attached to the axis of the mirror, and thus the axis can be adjusted in altitude and azimuth like an equatorial in the ordinary way by observing a star east and west on the meridian. A level is attached to the telescope, so that if the latitude be known the adjustment in altitude can be made very simply by setting the telescope to a south declination equal to the colatitude, and screwing up the instrument until the level bubble shows the telescope to be horizontal. A single observation of the Sun east or west will then suffice for the azimuth adjustment; or if the local time be known, and a cross level be provided for the pivots of the telescope, a transit observation of any object on the meridian will adjust in azimuth. As regards the accuracy of adjustment necessary, Dr. Schuster concludes (*Phil. Trans.* vol. clxxx. 1889, A, pp. 291–350) that an error of $3'$ or $4'$ is allowable in the position of the instrumental pole; for the Sun's motion in declination may be so large as to correspond to a maladjustment of this magnitude; while the error to be feared from indifferent clock-driving is greater. But assuming that the clock can be got to go well, the effect of the Sun's motion in declination may be allowed for by deliberately putting the instrumental pole slightly out of adjustment. The rule for the displacement may be readily deduced as follows:—

The Sun has practically two angular rotations, one round P, the Earth's pole, in one day; the other round E, the ecliptic pole, in $365\frac{1}{4}$ days and in the reverse direction. The resultant is a rotation round the pole Q in EP produced, where

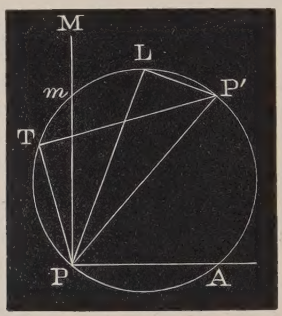
$$PQ = EQ/365\tfrac{1}{4} = 24°/360 \text{ (say)} = 4'.$$

The point Q revolves round P during the day, and hence we can only compensate the Sun's annual motion for one time of the day if the instrument is to remain undisturbed; but it will clearly be convenient to choose for this time the time of totality. The rule will then be: Adjust the instrument to the true pole, and then disturb its pole $4'$ in the direction opposite to

that in which the ecliptic pole lies at the hour of totality. The clock must of course keep *solar* time.

The final adjustments may perhaps be best made photographically. Pointing a telescope to the mirror, and letting the clock drive, take two photographs of the Sun at intervals of ten minutes, or even half an hour. The motion in declination can be measured on the photograph. Repeat the operation at another hour-angle. Then we have sufficient to give us completely the exact position of the instrumental pole.

If γ be the displacement of the instrumental pole from the true, K its hour-angle, then the declination of an object in hour-angle T will read apparently too great by $\gamma \cos (T-K)$. If we watch the *motion in declination* for one minute this will be a



decrease of $\cdot 0044\,\gamma \sin (T-K)$. A graphical construction will generally be sufficiently accurate for determining the displacement of the instrumental pole by either method. Consider, for instance, the first. Suppose we have observed the errors in declination at two hour-angles $-h_1$ and h_2 to be e_1 and e_2. Let P represent the pole and PM the meridian, and draw PT of length e_1 in the direction of the first hour-angle (*i.e.* $\angle \mathrm{TPM}=h_1$); PL of length e_2 in that of the second. Draw perpendiculars TP′, LP′ to PT and PL, meeting in P′, and on PP′ as diameter describe the circle PTLP′. Then P′ is the instrumental pole; and hence

$$\mathrm{PP}'=\gamma \text{ and } \angle \mathrm{MPP}'=\mathrm{K}.$$

For

$$\mathrm{PT}=\mathrm{PP}'\cos \mathrm{TPP}'=\gamma \cos (-h_1-\mathrm{K})$$
$$\mathrm{PL}=\mathrm{PP}'\cos \mathrm{LPP}'=\gamma \cos (h_2-\mathrm{K}).$$

The total displacement PP′ is compounded of a displacement Pm in altitude and PA $\times$ cosecant latitude in azimuth. The error in declination at any other hour-angle is found by drawing a line from P to the circumference of the circle.

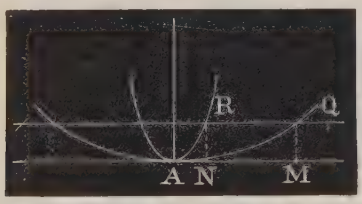
The modification of this construction for the *motion in declination* is tolerably obvious.

Adjustment of Mirror.

Only one adjustment concerns us—the parallelism of the face of the mirror to the axis of rotation. The instrument-maker may be trusted to get this nearly right; and since the mirror can be reversed in its pivots, we can soon detect any great want of parallelism by observing any terrestrial or celestial object by reflection from the mirror in a fixed telescope, and then reversing the mirror in its pivots. But it is not easy to get this adjustment quite exact. The mirror is held in its cell by three brass lugs, which are screwed up into a groove running round the edge; and the position it takes up is subject to slight alterations. For instance, the parallelism of the mirror was tested on March 31 at Oxford as follows:—

The Sun was swept into the telescope (by reflection from the mirror) and its image viewed on the ground glass. A piece of gummed paper was stuck on the glass and the path of the Sun marked on the paper with a pencil. The mirror was then reversed, and the Sun was found to travel about 20′ north of the previous mark. One of the three screws used to lower the mirror into its cell was then inserted into its socket and screwed into very gentle contact with the back of the mirror. The error was found to be over-corrected. The screw was then removed, but the mirror did not fall back, and the error remained over-corrected even after reversal. The arrangements for this adjustment need further investigation.

The *effect* of any want of adjustment is that the image of a star, instead of remaining stationary, would describe a small ellipse on the plate about its mean position, the axes of the ellipse being 4ψ and $4\psi \sin \delta$, where ψ is the tilt of the mirror to the polar axis, and δ the declination of the star, the minor axis of the ellipse being perpendicular to the polar axis (see Appendix). But



only the small portion of this ellipse corresponding to practicable positions of the mirror would be actually described, viz. that near one of the ends of the major axis. If A be such an apse, then, when the star and its image are in the same hour-circle, the image falls at A; but with lapse of time the image travels along a curve, AR or AQ, according to the declination of the star. The travelling along ANM goes into the clock-rate, and

it would make the clock-rate apparently different for objects of different declination.

The travelling perpendicular to AM is the same for all declinations. It is distinguished from such travelling, due to maladjustment of the polar axis, by being zero on the T.H.C., wherever this may be, and for all stars.

The following table gives the distance RN or QM for different times (but for all stars, whatever their declination) for a tilt of 10′ in the mirror :—

m	″	m	″
40	0·5	160	7·2
80	1·8	200	11·3
120	4·1	240	16·1

It thus appears that there is an advantage in using the mirror near the T.H.C. ; for the rate of change in this coordinate is only 0″·5 for the first half-hour, but ten times this amount four hours away.

It is clear, however, that for work on the Sun near the T.H.C. the motion arising from tilt is small, and if the adjustment is tolerably good may be neglected.

Some Useful Formulæ.

In the paper above cited Dr. Schuster gives "some formulæ which may be useful to future eclipse observers." As these notes may be in the hands of those who may not have Dr. Schuster's paper with them I reproduce the formulæ here. I would remark, however, that I think Dr. Schuster's fundamental supposition about resolving power (see p. 298 of his paper, *Phil. Trans.*, 1889 A), scarcely applicable to photographic resolving power. It is too small ; but a discussion of this point would be out of place here.

ϕ is the displacement in seconds of arc which is allowable, consistent with full definition.

R is the true aperture of the lens in centimetres.

R′ is the effective aperture of the lens in centimetres.

q is the time of exposure in seconds.

Q is the longest time of exposure compatible with full definition.

γ is the greatest allowable angle between the true pole and the pole of the instrument in seconds of arc.

T is the change of solar declination measured in seconds of arc per second of time.

e is the error of the clock-rate measured in per cent.

In equations (2) (4) (6) it is assumed that in adjusting the pole of the equatorial no account is taken of the change of the solar declination during the eclipse.

$$\phi = 2{\cdot}5/R \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$Q = 2{\cdot}5/RT \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\gamma = 34600/Rq \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Or if the longest exposure Q is to be used

$$\gamma = 13840\,T \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Finally to determine R′, we easily find

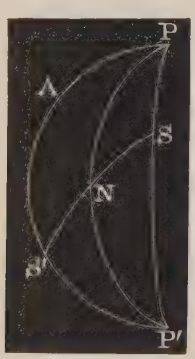
$$\frac{1}{R'} - \frac{1}{R} = 60 \times 10^{-} \times qe \quad . \quad . \quad . \quad . \quad (5)$$

This equation will allow us to determine the time of exposure allowable for a given effective aperture R′ if the clock-rate is known. If the longest exposure Q is to be used, we get

$$\frac{R - R'}{R'} = \frac{1{\cdot}5 \times 10^{-3} \times e}{T} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Appendix on the form of the closed curve on the sphere described by the reflected ray when the mirror is inclined to the polar axis.

Let P be the North Pole, P′ the South Pole, S a star, and S′ its image. N the normal to the mirror. When the adjustment is perfect, N bisects PNP′ and also SNS′, and the triangles SNP, S′NP′ are equal in all respects. The meridian PAS′P′ is



fixed, and S′ is a fixed point on it (since P′S′=PS=constant), and the meridian PNP′ containing the point N travels at half the rate of the meridian PSP′ containing the point S.

But suppose the mirror tilted at an angle ψ to the polar

axis so that PN is no longer $\frac{\pi}{2}$ but $\frac{\pi}{2}+\psi$. Then S′ no longer falls on PAP′ but we still have SN=NS′.

Also if the clock rate is properly adjusted

$$\angle \mathrm{SPN} = \angle \mathrm{APN} = \phi \text{ say.}$$

Now take in PN produced, NR=NP.

Then since

$$\mathrm{NR},\ \mathrm{NS}' = \mathrm{NP},\ \mathrm{NS}$$

and

$$\angle \mathrm{S}'\mathrm{NR} = \angle \mathrm{SNP},$$

the triangles S′NR, SNP are equal in all respects, so that

$$\mathrm{RS}' = \mathrm{PS} \text{ and } \angle \mathrm{S}'\mathrm{RN} = \angle \mathrm{NPS} = \phi = \angle \mathrm{AP}'\mathrm{N}.$$

Further,

$$\mathrm{P}'\mathrm{R} = 2\psi.$$

The locus of S is thus defined most simply by reference to the point P′, as follows :

R is any point on a small circle centre P′ and radius

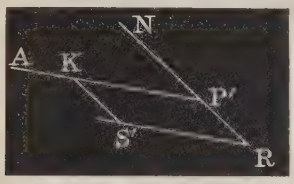
$$\mathrm{P}'\mathrm{R} = 2\psi.$$

From R is drawn RS′ of constant length RS′=p the N.P.D. of the star, and making with RP′ the same angle as the fixed meridian AP′ makes with RP′; *i.e.*

$$\angle \mathrm{AP}'\mathrm{N} = \angle \mathrm{S}'\mathrm{RP}'.$$

If the surface were a plane instead of a sphere, the locus would be a circle. For if in plane geometry

$$\angle AP'N = \angle S'RP'$$



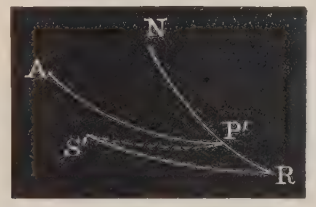
RS′ will be parallel to PA. And since RS′ is constant in length, if we take

$$P'K = RS',$$

then KS′RP′ is a parallelogram and

$$KS' = P'R,$$

and is constant in length. Thus S′ describes a circle about K.



But in spherical geometry the locus of S′ is more complicated. We have

$$\begin{aligned}
\sin P'S' \sin S'P'N &= \sin S'R \sin S'RP' \\
&= \sin p \sin \phi \\
\sin P'R \sin P'S' \cos S'P'N &= \cos P'R \cos P'S' - \cos S'R \\
&= \cos P'R(\cos P'R \cos S'R + \sin P'R \sin S'R \cos S'RP') - \cos S'R \\
&= -\cos S'R \sin^2 P'R + \cos P'R \sin P'R \sin S'R \cos S'RP'
\end{aligned}$$

Thus

$$\sin P'S' \cos S'P'N = -\cos p \sin 2\psi + \cos 2\psi \sin p \cos \phi.$$

Hence

$$\begin{aligned}
\sin P'S' \sin S'P'A &= \sin P'S' \sin (S'P'N - \phi) \\
&= \sin p \sin \phi \cos \phi - \sin \phi [\cos 2\psi \sin p \cos \phi - \cos p \sin 2\psi] \\
&= \sin \phi [\cos p \sin 2\psi + 2 \cos \phi \sin p \sin^2 \psi] \\
\sin P'S' \cos S'P'A &= \cos \phi [\cos 2\psi \sin p \cos \phi - \cos p \sin 2\psi] + \sin p \sin^2 \phi \\
&= \sin p - \cos \phi [\cos p \sin 2\psi + 2 \cos \phi \sin p \sin^2 \psi].
\end{aligned}$$

Now let

$$x' = \sin P'S' \cos S'P'A,\ y = \sin P'S' \sin S'P'A,$$

so that (x', y) are the rectangular coordinates of the orthogonal projection of S′ on the tangent plane at P′. Further let

$$x = \sin p - x';$$

so that (x, y) are rectangular coordinates on this plane referred to a new origin. Then if we put $x = r \cos \theta$, $y = r \sin \theta$, we have

$$r^2 = x^2 + y^2 = [\cos p \sin 2\psi + 2 \cos \phi, \sin p \sin^2 \psi]^2$$

and

$$\tan \theta = \frac{y}{x} = \tan \phi:$$

thus

$$\cos \phi = \pm \cos \theta.$$

Thus the equation to locus of (x, y) is in polar coordinates

$$r = a + b \cos \theta$$

where

$$a = \cos p \sin 2\psi,\ b = 2 \sin p, \sin^2 \psi.$$

This is the equation to a limaçon; and the locus of S′ is thus the orthogonal projection of a limaçon (drawn on the tangent plane at the South Pole) on to the sphere. The pole of the limaçon is at the point $x' = \sin p$, i.e. the projection of the point when the image would fall with perfect adjustment.

The shape of the limaçon depends on the ratio b/a. When this is zero or infinite the curve is a circle; when it is unity, a cardioid. This ratio is $\tan p \tan \psi$; and if ψ is small but finite, the cases of a circle are $p = 0$ and $\frac{\pi}{2}$; *i.e.* the images of a star exactly at the Pole or exactly at the equator. In the former case $(p = 0)$; we have $r = \sin 2\psi$ in the latter $\left(p = \frac{\pi}{2}\right)$ we have $r = 2 \sin^2 \psi \cos \theta$, the dimensions of the curve depending on the *square* of ψ and being thus of the second order. For a cardioid we have

$$p = \frac{\pi}{2} \pm \psi,$$

which indicates objects very near the equator.

Generally the maximum and minimum values of r are

$$a \pm b;\ \text{or } 2 \sin \psi \cos (p \pm \psi).$$

r is always positive if $p \pm \psi$ never exceeds $\frac{\pi}{2}$; but if this condition

is not fulfilled (*i.e.* for objects close to the equator) the cusp of the cardioid becomes a double point, and there are two loops to

the curve. But the dimensions of the curve are then very small, depending on ψ^2.

Generally the curve will be a closed oval though the curvature is reversed for a small portion of the curve. But since b depends on ψ^2 and a on ψ, the curve will not be very different from a circle, radius $\cos p \sin^2 \psi$.

But we must remember that the limaçon itself is only the projection of the curve on the sphere with which we are really concerned ; and for eclipse work we are dealing with the zodiac, and the projection is thus at a considerable angle. The tangent plane to the sphere in the neighbourhood of the image is inclined at an angle p to that on which the limaçon is drawn. Hence the dimensions parallel to axis of x are lengthened in the ratio $\sec p$; those parallel to y remaining nearly the same. Thus the curve will be something like an ellipse, the lengths of the axes being $2 \sin 2\psi$ and $2 \cos p \sin 2\psi$ respectively. This is the result quoted in the text.

Note on the Solution by Least Squares of the Equations arising in the Reduction of Photographic Star-plates. By Harold Jacoby.

In the determination of the constants of a photographic plate from the measured coordinates of known stars on the plate, we have to carry out the solution of a set of linear equations by the method of least squares or otherwise. The coefficients in these equations possess a peculiarity which will enable us to effect a rigorous least square solution with very little labour. If we indicate by p and r the scale value and orientation constants, and by k and c the two errors of centring, we shall have from the right ascensions of the known stars a series of equations of the form

$$ap + br + k + d' = 0.$$
$$\vdots \qquad \vdots$$

From the declinations we get another series of equations as follows :—

$$bp - ar + c + d = 0.$$
$$\vdots \qquad \vdots$$

If the number of stars be n, and if we indicate the summation of n quantities in the usual way by means of square brackets, the rigorous least square solution of the above $2n$ equations is given by the following formulæ :—

$$A = [aa] - \frac{[a]^2}{n},$$

$$C = [ad'] - \frac{[a]\,[d']}{n},$$

$$D = [bb] - \frac{[b]^2}{n},$$

$$E = [bd'] - \frac{[b]\,[d']}{n},$$

$$C' = [bd] - \frac{[b]\,[d]}{n},$$

$$E' = -[ad] + \frac{[a]\,[d]}{n},$$

$$p = -\frac{C + C'}{A + D}, \qquad \text{weight of } p = A + D,$$

$$r = -\frac{E + E'}{A + D}, \qquad \text{weight of } r = A + D,$$

$$k = -\frac{1}{n}\left\{[a]\,p + [b]\,r + [d']\right\}, \quad \text{weight of } k = n - \frac{[a]^2 + [b]^2}{[aa] + [bb]},$$

$$c = -\frac{1}{n}\left\{[b]\,p - [a]\,r + [d]\right\}, \quad \text{weight of } c = n - \frac{[a]^2 + [b]^2}{[aa] + [bb]}.$$

With the help of a Thomas or Brunsviga calculating machine, these formulæ enable us to perform a least square solution in a very short time indeed. As an example, let us take the following set of equations, which occurred in the discussion of a plate taken by M. Henry at Paris, 1891 December 2.

Equations derived from the Right Ascensions.

a	b	d'	*Res'l.*
$-37p$	$+15r$	$+k+3''\cdot03=0$	$+0''\cdot94$
$-33p$	$-2r$	$+k+2\cdot69=0$	$+0\cdot31$
$-24p$	$+13r$	$+k+1\cdot56=0$	$-0\cdot68$
$-19p$	$+11r$	$+k+1\cdot63=0$	$-0\cdot68$
$-16p$	$+16r$	$+k+2\cdot51=0$	$+0\cdot24$
$-p$	$-3r$	$+k+1\cdot93=0$	$-0\cdot74$
$+2p$	$-27r$	$+k+4\cdot16=0$	$+1\cdot11$
$+2p$	$-1r$	$+k+1\cdot97=0$	$-0\cdot70$
$+24p$	$0r$	$+k+1\cdot88=0$	$-0\cdot97$
$+32p$	$+33r$	$+k+3\cdot16=0$	$+0\cdot72$
$+34p$	$+17r$	$+k+3\cdot16=0$	$+0\cdot46$

Equations derived from the Declinations.

b	$-a$	d	*Res'l.*
$+15p$	$+37r$	$+c-15''\cdot15=0$	$-0''\cdot51$
$-2p$	$+33r$	$+c-14\cdot56=0$	$+0\cdot18$
$+13p$	$+24r$	$+c-15\cdot44=0$	$-0\cdot97$
$+11p$	$+19r$	$+c-13\cdot08=0$	$+1\cdot34$
$+16p$	$+16r$	$+c-14\cdot62=0$	$-0\cdot29$
$-3p$	$+r$	$+c-13\cdot41=0$	$+0\cdot87$
$-27p$	$-2r$	$+c-14\cdot77=0$	$-0\cdot32$
$-p$	$-2r$	$+c-14\cdot09=0$	$+0\cdot13$
$0p$	$-24r$	$+c-14\cdot46=0$	$-0\cdot57$
$+33p$	$-32r$	$+c-13\cdot19=0$	$+0\cdot29$
$+17p$	$-34r$	$+c-13\cdot73=0$	$-0\cdot13$

We have here—

$$n=11,$$

$$[a]=-36, \quad [b]=+72, \quad [d']=+27\cdot68, \quad [d]=-156\cdot50$$
$$[aa]=+6416, \quad [ad']=-45\cdot44, \quad [bb]=+2892, \quad [bd']=+156\cdot36$$
$$[bd]=-992\cdot22, \quad [ad]=+613\cdot78.$$

Consequently—

$$A=+6298\cdot18, \quad C=+45\cdot15, \quad D=+2420\cdot73, \quad E=-24\cdot82,$$
$$C'=+32\cdot14, \quad E'=-101\cdot61,$$

And therefore—

$p = -$ ·0089, weight 8719.
$r = +$ ·0145, „ 8719.
$k = -$ 2″64, „ 10·3
$c = +$ 14·24, „ 10·3.

If we substitute these values of the unknowns in the original equations, we get the series of residuals given above. The sum of the squares of the 22 residuals is 10·3179, so that we have—

Mean error of one equation $= \pm 0''.76$,
Mean error of p or r $= \pm 0{\cdot}0081$,
Mean error of k or c $= \pm 0{\cdot}24$.

The above method of computation is so simple, and requires so little time, that there seems to be no reason to substitute some other method for the method of least squares in the reduction of photographic plates. It should be noted, however, that in the foregoing computations all the equations received unit weight. But it might be desirable to give different weights to the equations derived from the declinations and right ascensions. In that case some of the simplicity of the solution here given is lost. But we can still employ a tolerably simple system of formulæ. If we compute, in addition to the auxiliaries already computed, the quantity—

$$B = [ab] - \frac{[a]\,[b]}{n},$$

and if we assume that the right ascension equations are to receive the weight w, and the declination equations the weight w', we can obtain the values of the unknown quantities, such as they result from a rigorous least square solution, by the following system of formulæ :—

$$\mu_1 = wA + w'D,$$
$$\mu_2 = (w - w')B,$$
$$\mu_3 = wC + w'C',$$
$$\mu_4 = wD + w'A,$$
$$\mu_5 = wE + w'E',$$
$$Q_1 = \mu_4 - \frac{\mu_2^2}{\mu_1}, \qquad Q_1' = \mu_4 - \frac{\mu_2^2}{\mu_4},$$
$$Q_2 = \mu_5 - \frac{\mu_2\mu_3}{\mu_1},$$
$$r = -\frac{Q_2}{Q_1}, \text{ weight of } r = Q_1,$$
$$p = -\frac{\mu_3 + \mu_2 r}{\mu_1}, \text{ weight of } p = Q_1',$$
$$k = -\frac{1}{n}\left\{[a]p + [b]r + [d']\right\}, \text{ weight of } k = wn, \text{ nearly.}$$
$$c = -\frac{1}{n}\left\{[b]p - [a]r + [d]\right\}, \text{ weight of } c = w'n, \text{ nearly.}$$

If now these values of the unknowns are substituted in the original equations, and if we indicate by v and v' the residuals from the right ascension and declination equations respectively, then we must use as the sum of the squares of the residuals for the computation of the mean error of one equation of weight unity, the quantity :—

$$w[vv] + w'[v'v'].$$

In some cases it may seem desirable to compute the unknowns separately from the right ascensions and declinations in order to see if they agree within the limits of their probable errors. In doing this we can make use of the auxiliaries given above. The necessary formulæ are as follows :—

Right Ascension Equations.

$$\nu_1 = \mathrm{D} - \frac{\mathrm{B}^2}{\mathrm{A}}, \qquad \nu_2 = \mathrm{E} - \frac{\mathrm{BC}}{\mathrm{A}},$$

$$r = -\frac{\nu_2}{\nu_1}, \text{ weight of } r = \nu_1,$$

$$p = -\frac{\mathrm{B}}{\mathrm{A}} r - \frac{\mathrm{C}}{\mathrm{A}}, \text{ weight of } p = \nu_3 \text{ (*see below*)},$$

$$k = -\frac{1}{n}\left\{[a]p + [b]r + [d']\right\}, \text{ weight of } k = n, \text{ nearly.}$$

Declination Equations.

$$\nu_3 = \mathrm{A} - \frac{\mathrm{B}^2}{\mathrm{D}}, \qquad \nu_4 = \mathrm{E}' + \frac{\mathrm{BC}'}{\mathrm{D}},$$

$$r = -\frac{\nu_4}{\nu_3}, \text{ weight of } r = \nu_3,$$

$$p = +\frac{\mathrm{B}}{\mathrm{D}} r - \frac{\mathrm{C}'}{\mathrm{D}}, \text{ weight of } p = \nu_1 \text{ (*see below*)},$$

$$c = -\frac{1}{n}\left\{[b]p - [a]r + [d]\right\}, \text{ weight of } c = n, \text{ nearly.}$$

It will be noticed that the computation of the unknowns from the right ascension and declination equations combined, and treated as a single set of equations, is much less laborious than the determination from either set of equations alone. It follows that when a solution from the two sets of equations has once been effected, the combined solution can be worked out with very little additional trouble. We know of no good reason, *a priori*, why the separate solutions should bring out different values of the unknowns. Only by the discussion of a large number of plates, for each of which the two separate solutions as well as the combined solution have been made, can we settle this question. In performing such solutions, the weights and probable errors of the unknowns must always be worked out. For we should not be justified in drawing a conclusion, unless the differences between the values obtained from the separate solutions were appreciably greater than might reasonably be expected after a consideration of their probable errors.

Photographs of the Spectra of twenty-three characteristic Helium Stars; also Photographs of the Spectra of six Stars of the Third Magnitude, showing the transitions from type to type. By F. McClean, LL.D., F.R.S.

The photographs shown represent a series of spectra of twenty-three stars, characterised by lines associated with the new element, helium. They have been taken during the last twelve months in the course of photographing the spectra of the northern stars down to the third magnitude. The group thus selected corresponds almost exactly with Class I.*a* of Lockyer's "Classification of Stellar Spectra" (*Phil. Trans.* December 1892). Helium was not then in question, but soon after its discovery Lockyer further attributed the characteristic spectrum of this class to that element (*Proc. Roy. Soc.* May 9, 1895).

The larger series of spectra mentioned will include about 160 stars. Photographs are shown of the spectra of six stars of the third magnitude, illustrating the transitions from type to type. The types are the original ones of Secchi, but Type I. is subdivided into five sections, including that of helium.

A scale of wave-lengths has been constructed by the usual method which will be sufficient to identify the lines. Dunér's Bands are indicated on the spectrum of α Herculis.

The instrument used is a photographic telescope made by Sir Howard Grubb. The object glass is of 12 inches aperture and 11 feet 3 inches focal length; a prism of the same aperture, with a refracting angle of 20°, is mounted in a hinged frame in front of the object glass; the cell of the prism also rotates in the plane of the frame; by this means the adjustment of the prism both in position and either on or off the object glass is effected with facility. The telescope was completed in 1895 May.

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Note.—A copy of the photographs will be deposited in the Library. They include the following stars:

Helium Stars.

1. Orion β	Mag. 1	13. Perseus δ	Mag. 3
2. „ γ	„ 2	14. „ ϵ	„ 3
3. „ δ	„ 2	15. „ ζ	„ 3
4. „ ϵ	„ 2	16. Lyra β	„ 3
5. „ ζ	„ 2	17. Pegasus γ	„ 3
6. „ ι	„ 3	18. Ursa Minor η	„ 2
7. „ κ	„ 3	19. Virgo α	„ 1
8. Auriga β	„ 2	20. Scorpio β	„ 2
9. Taurus β	„ 2	21. „ δ	„ 2
10. „ ζ	„ 3	22. „ π	„ 3
11. „ η	„ 3	23. „ σ	„ 3
12. Cassiopeia ϵ	„ 3		

Typical Stars.

Type	I.	Canis Minor β	Mag. 3
„	I.	Leo θ	„ 3
„	I.	„ δ	„ 3
„	I.	„ ζ	„ 3
„	II.	„ ϵ	„ 3
„	III.	Hercules α...	„ 3

Diameters of Jupiter measured with the Filar and Double-image Micrometers at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In 1895 June the results of the measures of *Jupiter's* diameters, made with a bi-filar micrometer attached to the 28-inch refractor, were communicated to the Society. At that time it was intimated that a few measures had also been made with the double-image micrometer, but that the results could not then be given, as the value of the micrometer-screw had not been ascertained. The observations have been continued, and the following are the results.

The method adopted was first to obtain a set of measures with the filar micrometer, and then a set with the double-image micrometer on the same evening. The 28-inch is well adapted for this, as the breech end is arranged for either direct or diagonal view by means of a plane mirror, which can be readily inserted or withdrawn. The bi-filar micrometer was mounted for direct view, and the double-image for diagonal view, by use of the plane mirror.

The adopted value of 1 rev. of the double-image micrometer is $4''{\cdot}151$, as ascertained by transits of a polar star on 1895 August 9.

The observations were made by Mr. Dyson and Mr. Lewis, and the results have been kept separate. Both observers made a few measures with a blue shade over the eye-piece, which made measuring easier.

The observations have all been reduced to mean distance $5{\cdot}2028$, and the correction for phase has been taken from Mr. Marth's Ephemeris in the *Monthly Notices*.

Measures by Mr. Dyson.

		Equatorial Diameter. Filar Micrometer.	Equatorial Diameter. Double-image Micrometer.	Filar − D. I.	Polar Diam. Filar Micrometer.
1896.		″	″	″	″
Feb.	6	38·455	37·837	+0·618	...
	11	38·257	37·778	+ ·479	...
Mar.	2	37·974	37·758	+ ·216	...
	23	38·368	38·353	+ ·015	35·926
	25	38·380	38·224	+ ·156	36·128
	30	38·601	38·697	− ·096	35·803
Apr.	15	38·335	38·398	− ·063	36·129
Mean		38·339	38·149	+ ·190	35·997

Measures by Mr. Lewis.

		Equatorial Diameter. Filar Micrometer.	Equatorial Diameter. Double-image Micrometer.	Filar − D. I.	Polar Diameter. Filar Micrometer.	Polar Diameter. Double-image Micrometer.	Filar − D. I.
1896.		″	″	″	″	″	″
Feb.	4	38·153	37·310	+0·843	...	...	...
	6	·358	·235	1·123	...	...	...
	10	·280	·688	0·592	...	...	...
	18	·190	·579	0·611	...	...	...
	22	·395	·832	0·563	...	...	...
Mar.	3	·439	·431	1·038	35·957	35·249	+0·708
	5	...	...	....	36·030	...	...
	27	·076	·630	0·446	36·170	35·176	·994
	31	·138	·242	0·896	35·883	35·136	·746
Apr.	3	·051	·366	0·685	36·172	35·413	·759
	8	·212	·355	0·857	35·881	35·541	·340
	18	·115	·350	+0·765	36·029	35·655	+ ·374
Mean		38·219	37·456	+0·763	36·017	35·362	+0·655

If we compare the measures of the equatorial and polar diameters taken with the same micrometer it is clearly shown that the polar diameter is much more easy to measure; a fact which was felt during the observations. Of course this is in part due to the clock, and in part to the imperfection of the limb due to phase, this latter defect being very apparent where the east and west limbs were brought into contact in the double-image micrometer.

It will be seen that the filar micrometer not only gives more consistent results, but also shows less personality, the measures

of the two observers with it being in close agreement, while there is a large systematic difference between the measures made with the double-image micrometer.

Using, in addition to the observations above, three sets of observations made by Mr. Lewis in 1895, we get

	Filar Micrometer — Double-image Micrometer. Equatorial Diam.	Polar Diam.
Mr. Dyson, 1896	+0″·190	...
„ Lewis, 1896	+0·763	+0·655
„ „ 1895	+0·912	...
Weighted Mean	+0·593	+0·655

or combining both diameters :

$$\text{Filar} - \text{D. I.} = +0''{\cdot}609$$

The following comparison of the values obtained by different methods may be of interest :—

	Heliometer. Equat. Diam.	Polar Diam.		Double-image. Equat. Diam.	Polar Diam.		Filar Micrometer. Equat. Diam.	Polar Diam.
Bessel	37″·60	35″·21	Kaiser	37″·55	35″·15	W. Struve	38″·33	35″·54
Winnecke	37·43	35·11	Main	37·91	35·67	Secchi	38·35	35·96
Johnson	37·38	35·13	Dyson	38·15	...	Barnard	38·52	36·11
Main	37·00	35·00	Lewis	37·46	35·36	{Dyson and Lewis}	38·27	36·01
	37·35	35·11		37·77	35·39		38·37	35·90

Royal Observatory, Greenwich :
1896 *May* 5.

PHILOSOPHICAL
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Observations of Comets a 1896 (*Perrine-Lamp*) *and b* 1896 (*Swift*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks' Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time. 1896.	d	h	m	s	Observer.	☄−✶R.A. m	s	Corr. for Refraction. s	Log factor of Parallax.	☄−✶N.P.D. ′	″	Corr. for Refraction. ″	Log factor of Parallax.	No. of Comps.	Apparent R.A. of ☄ h	m	s	Apparent N.P.D. of ☄ °	′	″	Comp. Star.
Observations of Comet a 1896.																					
Apr.	12	9	4	2	B.	+0	48·25	+0·01	9·6870	−10	55·9	−0·1	0·7119	4	4	34	2·93	49	10	8·5	*a*
	13	9	9	7	,,	+2	14·33	0·00	9·6862	− 4	19·3	−0·1	0·7227	4	4	35	28·99	49	16	45·2	*a*
Observations of Comet b 1896.																					
Apr.	20	8	17	41	B.	+0	33·98	−0·06	9·6140	+ 8	43·4	+0·5	0·8153	2		...			...		*b*
	20	8	20	13	,,	−0	14·44	−0·02	9·6129	+ 2	35·4	+0·3	0·8174	2	3	34	42·22	61	50	20·4	*c*
	20	8	24	13	A. C.	−0	14·39	−0·02	9·6115	+ 2	0·8	+0·2	0·8201	4	3	34	42·27	61	49	45·7	*c*
	20	8	25	15	,,	−1	8·61	+0·10	9·6113	−11	41·0	−1·0	0·8206	1	3	34	41·76	61	49	48·4	*d*
	21	8	32	51	,,	+1	53·33	+0·04	9·6164	− 6	4·7	−0·5	0·8240	6	3	32	55·98	59	7	12·6	*e*
	23	8	52	45	H.	+3	14·34	+0·02	9·6206	− 3	22·8	−0·4	0·8362	7	3	28	21·37	53	48	45·4	*f*
	26	8	45	38	B.	−1	0·63	+0·05	9·6554	−13	14·5	−1·0	0·8276	4	3	18	51·46	46	29	7·9	*g*
	26	8	45	38	,,	−2	38·68	+0·03	9·6554	− 7	14·3	−0·6	0·8276	4	3	18	51·58	46	29	5·8	*h*
	26	9	6	1	A. C.	−2	41·38	+0·05	9·6331	− 9	7·2	−1·0	0·8467	2	3	18	48·90	46	27	12·5	*h*

Greenwich Mean Solar Time.					Observer.	☄−★R.A.	Corr. for Refraction.	Log factor of Parallax.	☄−★N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Apparent R.A. of ☄	Apparent N.P.D. of ☄	Comp. Star.
1896.	d	h	m	s		m s	s		′ ″	″			h m s	° ′ ″	
Apr.	27	8	33	10	B.	+1 43·57	−0·01	9·6763	+ 2 51·7	+0·2	0·8153	4	3 15 3·48	44 15 24·3	*k*
	28	8	34	59	A. C.	+1 30·09	0·00	9·6840	+ 1 21·7	+0·1	0·8173	5	3 10 51·03	42 7 26·0	*l*
	29	8	48	56	B.	+1 26·85	0·00	9·6757	− 2 9·2	−0·2	0·8325	4	3 6 16·22	40 5 31·1	*m*
May	1	9	24	38	H.	−3 41·99	−0·02	9·6211	+ 6 8·7	+0·7	0·8662	6	2 56 9·93	36 23 28·8	*n*
	2	9	29	33	B.	+0 16·70	−0·02	9·6097	+11 6·7	+1·5	0·8722	4	2 50 40·80	34 44 9·2	*o*
	3	9	23	24	C.	+0 13·09	0·00	9·6179	+ 2 30·7	+0·3	0·8698	4	2 45 0·24	33 12 44·4	*p*
	3	9	26	5	A. C.	+0 12·27	0 00	9·6113	+ 2 23·5	+0·2	0·8717	6	2 44 59·42	33 12 37·1	*p*
	4	9	5	4	B.	−0 50·68	0·00	9·6529	+ 1 9·6	+0·1	0·8574	4	2 39 7·43	31 48 36·2	*q*
	4	9	14	23	C.	−0 54·04	0·00	9·6324	+ 0 25·4	+0·1	0·8655	2	2 39 4·07	31 47 52·0	*q*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

April 12.—Comet exceedingly faint.

„ 13.—Comet extremely faint. Observations difficult and doubtful. Sky not quite clear.

„ 20.—Comet bright with condensation. Visible in bright twilight.

„ 21.—Sky hazy. Comet less clear than on previous night. Still readily visible in twilight.

May 1.—The comet had a distinct condensation.

The initials C., H., A. C., B., are those of Mr. Cowell, Mr. Hollis, Mr. Crommelin, and Mr. Bryant respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0. h m s	Assumed N.P.D. 1896·0. ° ′ ″	Authority.
a	WB (2) IV. 658	4 33 14·30	49 21 18·3	Bonn Astr. Gesell. Catalogue, Paris Catalogue, 1875.
b	BD + 28° No. 560	3 34 8	61 42	Bonn Observations, vol. iv.
c	BD + 28° No. 563	3 34 56·58	61 47 53·6	Pulkova Catalogue (Romberg), 1875.
d	WB (2) III. 726	3 35 50·16	62 1 39·4	Weisse's Bessel (2).
e	Piazzi III. 96	3 31 2·55	59 13 27·0	Leiden Astr. Gesell. Zones 11, 243.
f	Lalande 6438	3 25 7·04	53 52 18·1	Lund. Astr. Gesell. Zones 75, 79, XV.
g	Groombridge 663	3 19 52·24	46 42 33·2	Greenwich Observations, 1894.
h	Groombridge 680	3 21 30·42	46 36 30·7	,, ,, 1894, 1895.
k	OA (N) 3666	3 13 20·21	44 12 42·1	Bonn Astr. Gesell. Catalogue.
l	Groombridge 635	3 9 21·31	42 6 13·7	Greenwich Observations, 1891, 1893.
m	BD + 49°, No. 871	3 4 49·82	40 7 49·8	Bonn Astr. Gesell. Catalogue.
n	OA (N) 3433	2 59 52·57	36 17 28·4	Cambridge (U.S.) Astr. Gesell. Catalogue.
o	Lalande 5356	2 50 24·87	34 33 9·4	Helsingfors-Gotha Astr. Gesell. Catalogue.
p	Lalande 5202	2 44 47·99	33 10 21·3	,, ,, ,, ,, ,,
q	BD + 58°, No. 519	2 39 59·06	31 47 33·9	,, ,, ,, ,, ,,

BD + 28°, No. 563, is the double star Σ 429. The companion star is of the 11th magnitude.

Piazzi III. 96. The proper motion of −0ˢ·0077 has been applied in R.A. deduced from comparison with Piazzi, Lalande, and Weisse's Bessel (2).

Royal Observatory, Greenwich:
1896 *May* 8.

Ephemeris of the Satellites of Mars, 1896–97. By A. Marth.

Professor Hermann Struve has been good enough to communicate, in advance of the publication of his observations of the satellites, the results which he has deduced for the longitudes l and mean motions n of the satellites, and also for the semi-axes a of their orbits. His values are ($l = w + \mathrm{N}$, w being the orbital longitude reckoned from N, the ascending node of the orbit on the plane parallel to the Earth's equator) for 1894 October 0·0 Greenwich :

Phobos $l_1 = 296^\circ 20$ $n_1 = 1128^\circ 84394$ $a_1 = 12''948$ at dist. 1.
Deimos $l_2 = 186 \cdot 38$ $n_2 = 285 \cdot 16194$ $a_2 = 32 \cdot 321$

Adopting these values, and referring the positions of the satellites to the assumed plane of the planet's equator, the data of the "Ephemeris for physical observations of *Mars*" become available, and the areocentric longitudes $l - \mathrm{L}$ of the satellites reckoned from the point of their orbits in opposition to the Earth, and the semidiameters $a\ b$ of the apparent orbits, will be :

		Phobos.			*Deimos.*		
Greenwich Noon. 1896.	P+90°	a_1	b_1	$l_1 - \mathrm{L}$	a_2	b_2	$l_2 - \mathrm{L}$
Sept. 9	56°·58	13″·49	−0″·68	329°·48	33″·74	−1″·71	250°·11
11	56·92	13·66	0·60	66·33	34·17	1·49	99·54
13	57·27	13·83	0·51	163·21	34·60	1·27	308·99
15	57·62	14·01	0·42	260·11	35·05	1·05	158·46
17	57·97	14·19	0·33	357·03	35·51	0·83	7·96
19	58·32	14·38	0·25	93·96	35·99	0·62	217·48
21	58·66	14·58	0·16	190·92	36·48	0·40	67·02
23	59·00	14·78	−0·08	287·90	36·98	−0·19	276·58
25	59·34	14·99	+0·01	24·91	37·50	+0·02	126·16
27	59·67	15·20	0·09	121·94	38·03	0·23	335·77
29	60·00	15·42	0·17	219·00	38·58	0·43	185·41
Oct. 1	60·32	15·64	0·25	316·09	39·14	0·63	35·07
3	60·62	15·87	0·33	53·20	39·72	0·82	244·76
5	60·92	16·11	0·40	150·34	40·31	1·00	94·48
7	61·20	16·35	+0·47	247·52	40·92	+1·18	304·23
9	61·47	16·60	0·54	344·72	41·54	1·35	154·01
11	61·73	16·86	0·60	81·96	42·18	1·51	3·83
13	61·97	17·12	0·66	179·23	42·83	1·66	213·68

Greenwich Noon. 1896.	P+90°	a_1	b_1	*Phobos.* l_1-L	a_2	*Deimos.* b_2	l_2-L
	°	″	″	°	″	″	°
Oct. 15	62·19	17·38	0·72	276·54	43·49	1·79	63·57
17	62·39	17·65	0·77	13·89	44·17	1·92	273·50
19	62·58	17·93	+0·81	111·27	44·86	+2·03	123·46
21	62·74	18·21	0·85	208·69	45·56	2·13	333·46
23	62·88	18·50	0·88	306·16	46·28	2·21	183·51
25	63·00	18·79	0·90	43·67	47·00	2·27	33·60
27	63·09	19·08	0·92	141·22	47·73	2·31	243·74
29	63·16	19·37	0·93	238·81	48·46	2·33	353·92
31	63·20	19·66	+0·93	336·45	49·19	+2·32	304·15
Nov. 2	63·21	19·95	0·92	74·14	49·93	2·29	154·43
4	63·20	20·25	0·90	171·88	50·66	2·24	4·76
6	63·15	20·54	0·86	269·67	51·38	2·16	215·14
8	63·08	20·82	0·82	7·51	52·08	2·05	65·57
10	62·98	21·09	0·77	105·40	52·77	1·91	276·05
12	62·85	21·36	+0·70	203·33	53·44	+1·74	126·59
14	62·69	21·61	0·62	301·31	54·08	1·54	337·17
16	62·50	21·85	0·52	39·34	54·68	1·31	187·80
18	62·29	22·08	0·41	137·41	55·24	1·04	38·48
20	62·05	22·29	0·30	235·53	55·76	0·75	249·21
22	61·79	22·47	0·17	333·69	56·23	0·43	99·98
24	61·51	22·64	+0·03	71·89	56·64	+0·08	310·79
26	61·21	22·78	−0·12	170·12	56·98	−0·28	161·64
28	60·89	22·89	0·27	268·38	57·26	0·67	12·53
30	60·57	22·97	0·43	6·67	57·47	1·08	213·45
Dec. 2	60·23	23·02	0·60	104·98	57·59	1·49	74·39
4	59·88	23·04	0·77	203·31	57·64	1·91	285·35
6	59·53	23·02	0·93	301·65	57·60	2·34	136·32
8	59·19	22·97	−1·10	39·99	57·47	−2·76	347·30
10	58·85	22·89	1·26	138·33	57·27	3·16	198·29
12	58·51	22·77	1·42	236·66	56·98	3·55	49·28
14	58·19	22·63	1·57	334·98	56·61	3·92	260·25
16	57·88	22·45	1·71	73·28	56·16	4·26	111·21
18	57·58	22·24	1·83	171·56	55·65	4·58	322·15
20	57·30	22·01	−1·95	269·81	55·07	−4·87	173·06
22	57·04	21·75	2·05	8·02	54·42	5·13	23·94
24	56·79	21·47	2·14	106·19	53·72	5·35	234·79
26	56·57	21·18	2·21	204·33	52·98	5·53	85·60
28	56·37	20·86	2·27	302·42	52·20	5·68	296·38

Greenwich Noon. 1896.	P+90°	a_1	b_1		*Phobos.* l_1-L	a_2	*Deimos.* b_2	l_2-L
	°	″	″		°	″	″	°
Dec. 30	56·19	20·53	2·32		40·47	51·38	5·80	147·11
Jan. 1	56·03	20·19	−2·35		138·47	50·53	−5·88	357·79
3	55·89	19·85	2·37		236·41	49·66	5·93	208·43
5	55·77	19·49	2·38		334·31	48·77	5·95	59·02
7	55·68	19·13	2·38		72·16	47·87	5·94	269·57
9	55·61	18·77	2·36		169·95	46·96	5·90	120·06
11	55·55	18·41	2·33		267·69	46·05	5·84	330·50
13	55·52	18·05	−2·30		5·38	45·15	−5·76	180·90
15	55·50	17·69	2·26		103·02	44·25	5·65	31·25
17	55·51	17·33	2·21		200·61	43·36	5·53	241·55
19	55·53	16·98	2·15		298·16	42·48	5·39	91·80
21	55·57	16 63	2·09		35·66	41·62	5·23	302·02
23	55·62	16·29	2·03		133·12	40·77	5·07	152·19
25	55·69	15·96	−1·96		230·53	39·93	−4·89	2·32
27	55·78	15·63	1·88		327·90	39·12	4·71	212·41
29	55·88	15·31	1·80		65·23	38·32	4·51	62·46
31	56·00	15·00	1·72		162·52	37·54	4·31	272·47
Feb. 2	56·14	14·70	1·64		259·78	36 78	4·11	22·45
4	56·29	14·40	1·56		357·00	36·04	3·90	332·39
6	56·45	14·12	−1·48		94·19	35·32	−3·69	182·30
8	56·63	13·84	1·39		191·34	34·62	3·48	32·18
10	56·83	13·57	1·30		288·46	33·94	3·26	242·03
12	57·04	13·30	1·22		25·56	33·28	3·04	91·85
14	57·27	13·05	1·13		122·62	32·65	2·82	301·65
16	57·51	12·80	1·04		219·66	32·03	2·61	151·42

The differences of successive values of l_1-L vary between 2256°·85 and 2258°·34, and of l_2-L between 569°·43 and 570°·99.

The values of P, a, b, $l-L$ being interpolated directly for the times for which the positions of the satellites are required, the rectangular coordinates x and y of the satellites referred to the axes of the planet's disc, or their position-angles p and apparent distances s are found by means of the formulæ

$$x = s \sin (p-P) = a \sin (l-L)$$
$$y = s \cos (p-P) = b \cos (l-L) + a \cos B \,.\, \sin \gamma \sin (l-\Gamma),$$

where the inclinations γ and nodes Γ of the satellite's orbits referred to the assumed plane of the planet's equator have the following values :—

		γ_1	$O-\Gamma_1$	γ_2	$O-\Gamma_2$	δl_2
		°	°	°	°	°
1896, Sept.	17	0·920	169·8	0·979	231·44	−0·014
Oct.	6	·920	178·6	0·988	231·82	·016
	27	·920	187·3	0·966	232·09	·018
Nov.	16	·920	196·1	1·002	232·31	·020
Dec.	6	0·921	204·8	1·005	232·52	−0·023
	26	·922	213·6	1·007	232·77	·026
1897, Jan.	15	·923	222·3	1·007	233·10	·028
Feb.	4	·924	231·3	1·006	233·53	·029
	24	0·925	239·7	1·005	234·08	−0·029

These values have been derived from H. Struve's statements (*Astron. Nachr.* No. 3302) by means of equations which are analogous to those for *Jupiter's* satellites (*Monthly Notices*, vol. li. p. 513).

$$\gamma_1 \sin (O-\Gamma_1) = \quad + \ 0°.93 \sin G_1$$
$$\gamma_1 \cos (O-\Gamma_1) = 0°.01 + 0°.93 \cos G_1$$
$$\gamma_2 \sin (O-\Gamma_2) = \quad + \ 1°.72 \sin G_2 - 0°.016 \sin 2 (O-l_0)$$
$$\gamma_2 \cos (O-\Gamma_2) = 0°.93 + 1°.72 \cos G_2 - 0°.016 \cos 2 (O-l_0)$$
$$\text{in which } G_1 = 227°.6 + 158°.0 \ (T-1894.80)$$
$$G_2 = 193°.7 + 6°.374 \ (T-1894.80)$$

and l_0 denotes the planet's mean longitude.

δl_2 is the effect of the Sun's perturbation on the longitude l_2 of *Deimos*.

Greenwich times at which the satellites will be at their greatest elongations (*e* in position P+90° and *w* in position P−90°), the designation in the case of *Phobos* belonging to both given times, so that an elongation on the opposite side occurs at mid-time between them.

	Phobos.		*Deimos.*			*Phobos.*		*Deimos.*	
1896.	h m		h m		1896.	h m		h m	
Sept. 9	14 3	*w*	21 42	16 51 *e*	Sept. 18	16 15	*e*	23 55	13 10 *e*
10	13 1	*w*	20 40	23 12 *e*	19	15 14	*e*	22 53	19 36 *e*
11	15 49	*e*	23 28	14 22 *w*	20	14 12	*e*	21 51	10 46 *w*
12	14 47	*e*	22 27	20 43 *w*	21	13 10	*e*	20 49	17 6 *w*
13	13 45	*e*	21 25	11 53 *e*	22	15 58	*w*	23 37	23 27 *w*
14	12 43	*e*	20 23	18 14 *e*	23	14 56	*w*	22 35	14 37 *e*
15	15 31	*w*	23 11	24 34 *e*	24	13 54	*w*	21 33	20 57 *e*
16	14 30	*w*	22 9	15 45 *w*	25	12 52	*w*	20 31	12 7 *w*
17	13 28	*w*	21 7	22 5 *w*	26	15 40	*e*	23 19	18 27 *w*

1896.	*Phobos.* h	m		h	m	*Deimos.* h	m	
Sept. 27	14	38	*e*	22	17	24	48	*w*
28	13	36	*e*	21	15	15	58	*e*
29	12	34	*e*	20	13	22	18	*e*
30	15	22	*w*	23	1	13	28	*w*
Oct. 1	14	20	*w*	21	59	19	48	*w*
2	13	18	*w*	20	57	10	58	*e*
3	12	16	*w*	19	55	17	17	*e*
4	15	4	*e*	22	43	23	37	*e*
5	14	2	*e*	21	41	14	47	*w*
6	13	0	*e*	20	39	21	7	*w*
7	15	47	*w*	23	27	12	17	*e*
8	14	45	*w*	22	25	18	36	*e*
9	13	43	*w*	21	23	24	56	*e*
10	12	41	*w*	20	21	16	6	*w*
11	15	29	*e*	23	8	22	25	*w*
12	14	27	*e*	22	6	13	35	*e*
13	13	25	*e*	21	4	19	54	*e*
14	12	23	*e*	20	2	11	4	*w*
15	15	10	*w*	22	50	17	23	*w*
16	14	8	*w*	21	47	23	42	*w*
17	13	6	*w*	20	45	14	52	*e*
18	12	4	*w*	19	43	21	11	*e*
19	14	51	*e*	22	31	12	20	*w*
20	13	49	*e*	21	29	18	39	*w*
21	12	47	*e*	20	26	24	58	*w*
22	11	45	*e*	19	24	16	8	*e*
23	14	32	*w*	22	12	22	26	*e*
24	13	30	*w*	21	9	13	36	*w*
25	12	28	*w*	20	7	19	54	*w*
26	11	26	*w*	19	5	11	3	*e*
27	14	13	*e*	21	52	17	22	*e*
28	13	11	*e*	20	50	23	40	*e*
29	12	9	*e*	19	48	14	49	*w*
30	11	6	*e*	18	46	21	7	*w*
31	13	54	*w*	21	33	12	16	*e*
Nov. 1	12	51	*w*	20	31	18	34	*e*
2	11	49	*w*	19	28	9	43	*w*
3	10	47	*w*	18	26	16	1	*w*

1896.	*Phobos.* h	m		h	m	*Deimos.* h	m	
Nov. 4	13	34	*e*	21	13	22	19	*w*
5	12	32	*e*	20	11	13	28	*e*
6	11	29	*e*	19	8	19	46	*e*
7	10	27	*e*	18	6	10	55	*w*
8	13	14	*w*	20	53	17	12	*w*
9	12	12	*w*	19	51	23	29	*w*
10	11	9	*w*	18	48	14	38	*e*
11	10	7	*w*	17	46	20	55	*e*
12	12	54	*e*	20	33	12	4	*w*
13	11	51	*e*	19	30	18	21	*w*
14	10	49	*e*	18	28	9	29	*e*
15	9	46	*e*	17	25	15	46	*e*
16	12	33	*w*	20	13	22	3	*e*
17	11	31	*w*	19	10	13	12	*w*
18	10	28	*w*	18	7	19	28	*w*
19	9	26	*w*	17	5	10	37	*e*
20	12	13	*e*	19	52	16	53	*e*
21	11	10	*e*	18	49	23	10	*e*
22	10	7	*e*	17	47	14	18	*w*
23	12	54	*w*	20	34	20	34	*w*
24	11	52	*w*	19	31	11	42	*e*
25	10	49	*w*	18	28	17	58	*e*
26	9	46	*w*	17	26	9	7	*w*
27	12	33	*e*	20	12	15	23	*w*
28	11	31	*e*	19	10	21	39	*w*
29	10	28	*e*	18	7	12	47	*e*
30	9	25	*e*	17	4	19	3	*e*
Dec. 1	12	12	*w*	19	51	10	11	*w*
2	11	9	*w*	18	49	16	27	*w*
3	10	7	*w*	17	46	22	43	*w*
4	9	4	*w*	16	43	13	51	*e*
5	11	51	*e*	19	30	20	6	*e*
6	10	48	*e*	18	27	11	14	*w*
7	9	46	*e*	17	25	17	20	*w*
8	8	43	*e*	16	22	8	38	*e*
9	11	30	*w*	19	9	14	54	*e*
10	10	27	*w*	18	6	21	10	*e*
11	9	24	*w*	17	3	12	17	*w*

	Phobos.			*Deimos.*				*Phobos.*			*Deimos.*		
1896.	h	m		h	m	h	m	1897.	h	m		h	m	h	m
Dec. 12	8	22	*w*	16	1	18	33 *w*	Jan. 13	9	27	*e*	17	6	7	30 *w*
13	11	8	*e*	18	48	9	41 *e*	14	8	25	*e*	16	4	13	48 *w*
14	10	6	*e*	17	45	15	57 *e*	15	7	23	*e*	15	2	4	57 *e*
15	9	3	*e*	16	42	22	13 *e*	16	6	20	*e*	14	0	11	15 *e*
16	8	0	*e*	15	39	13	21 *w*	17	9	8	*w*	16	47	17	33 *e*
17	10	47	*w*	18	26	19	37 *w*	18	8	5	*w*	15	45	8	42 *w*
18	9	45	*w*	17	24	10	45 *e*	19	7	3	*w*	14	43	15	0 *w*
19	8	42	*w*	16	21	17	1 *e*	20	6	1	*w*	13	40	6	9 *e*
20	7	39	*w*	15	18	8	9 *w*	21	8	49	*e*	16	28	12	27 *e*
21	10	26	*e*	18	5	14	25 *w*	22	7	46	*e*	15	26	18	46 *e*
22	9	24	*e*	17	3	20	41 *w*	23	6	44	*e*	14	24	9	56 *w*
23	8	21	*e*	16	0	11	50 *e*	24	5	42	*e*	13	21	16	15 *w*
24	7	18	*e*	14	58	18	6 *e*	25	8	30	*w*	16	9	7	24 *e*
25	10	5	*w*	17	45	9	14 *w*	26	7	27	*w*	15	7	13	43 *e*
26	9	3	*w*	16	42	15	30 *w*	27	6	25	*w*	14	5	4	51 *w*
27	8	0	*w*	15	39	6	39 *e*	28	5	23	*w*	13	3	11	10 *w*
28	6	58	*w*	14	37	12	55 *e*	29	8	11	*e*	15	50	17	29 *w*
29	9	45	*e*	17	24	19	12 *e*	30	7	9	*e*	14	48	8	38 *e*
30	8	42	*e*	16	21	10	20 *w*	31	6	7	*e*	13	46	14	57 *e*
31	7	40	*e*	15	19	16	37 *w*	Feb. 1	5	5	*e*	12	44	6	6 *w*
								2	7	52	*w*	15	32	12	25 *w*
1897.															
Jan. 1	6	37	*e*	14	16	7	45 *e*	3	6	50	*w*	14	30	18	45 *w*
2	9	24	*w*	17	4	14	2 *e*	4	5	48	*w*	13	28	9	54 *e*
3	8	22	*w*	16	1	5	11 *w*	5	8	36	*e*	16	15	16	13 *e*
4	7	20	*w*	14	59	11	28 *w*	6	7	34	*e*	15	13	7	23 *w*
5	6	17	*w*	13	56	17	45 *w*	7	6	32	*e*	14	11	13	42 *w*
6	9	4	*e*	16	44	8	54 *e*	8	5	30	*e*	13	9	4	52 *e*
7	8	2	*e*	15	41	15	11 *e*	9	8	18	*w*	15	57	11	11 *e*
8	7	0	*e*	14	39	6	19 *w*	10	7	16	*w*	14	55	17	31 *e*
9	9	47	*w*	17	26	12	37 *w*	11	6	14	*w*	13	53	8	41 *w*
10	8	44	*w*	16	24	18	54 *w*	12	9	2	*e*	16	41	15	1 *w*
11	7	42	*w*	15	21	10	3 *e*	13	8	0	*e*	15	39	6	10 *e*
12	6	40	*w*	14	19	16	21 *e*	14	6	58	*e*	14	37	12	30 *e*

As it is, perhaps, feasible to secure trustworthy observations of the eclipses of *Deimos* near the beginning and ending of the next cycle of eclipses, I give, not only the Greenwich mean times of the satellite's conjunctions with the centre of the shadow cone, but also the computed semi-durations of the eclipses according to the data adopted in the present ephemeris, it being understood

that these semi-durations are liable to considerable uncertainty, and intended merely for guidance. It is essential that the observed disappearances and reappearances of the satellite should refer to corresponding phases, and it is to be hoped that all the most powerful telescopes will be made to contribute.

1896.	Conj. or Middle of Eclipse. h m	Semi-duration. m	1897.	Middle of Eclipse or Conj. h m	Semi-duration. m
Nov. 6	10 6	...	Jan. 12	10 32	∓30
7	16 27	...	13	16 53	29
8	22 48	∓10	14	23 14	27
10	5 9	15	16	5 35	26
11	11 30	18	17	11 55	24
12	17 51	21	18	18 16	22
14	0 12	23	20	0 37	20
15	6 33	25	21	6 58	17
16	12 54	27	22	13 18	14
17	19 15	29	23	19 39	∓9
19	1 36	30	25	2 0	
20	7 57	∓31	26	8 21	

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